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The effects of vestibular vertigo produced by the rotating-chair method on the production and reproduction of time durations.

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THE EFFECTS OF VESTIBULAR VERTIGO PRODUCED BY THE ROTATING-CHAIR METHOD ON THE PRODUCTION AND REPRODUCTION OF TIME DURATIONS

by

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ABSTRACT

This study was designed to investigate the effects of vestibular vertigo produced by the rotating-chair method on the production and reproduction of time durations.

The experimental group consisted of ten subjects who received both conditions of rotation and non-rotation while making estimates under the method of production and the method of reproduction on the standard stimulus intervals 2", 5", 7", and 10". The apparatus consisted of a rotating-chair, tone producer, tape recorder for giving standard instructions, and a recording clock. Rotation of subjects was accomplished manually using an acceleration-deceleration, energy pulse system.

Results were analyzed both by statistical analyses of variance; orthogonal tests for trends; and graphically using both ordinary graphic materials and log.-log. graphic materials. Scores for the analyses were in the form of total deviation scores and mean estimate scores.

These tests indicated that vestibular vertigo had no effect on the estimation of the time intervals specified. The results also showed that there was some basis for the assumption that the two methods of time estimation used were founded on different underlying basis. The method of reproduction was found to demonstrate a larger variability of error than the other method, but no differences were evident to show variation between the two methods in terms of average estimates, or average error.

The average error of both methods was found to always be negative. That is, subjects produced and reproduced shorter estimates than the standard stimulus intervals. Increases in estimate durations varied directly in proportion with the magnitude of the stimulus interval and were best described by linear graphic resresentation only. The increases in estimate duration were found to vary as a power function with magnitude of stimulus intervals.

PREFACE

This research was initiated as a result of the author's interest in the possibilities of the use of distortion of the time sense by rotation in the facilitation of psychological conversion (ie. 'brainwashing'). It was decided to test whether or not rotation and vertigo was a workable factor in the distortion of the human time sense, specifically distortion of the abililty to estimate time intervals.

The author wishes to express his gratitude to Dr. Byron P. Rourke, Mr. Donald H. Richardson M.A., and Rev. J. R. Dougherty C.S.B., M.Sc., for their kind direction and aid in this investigation. My special gratitude to Rev. G. Freemesser C.S.B., M.D. for his most generous donation of time and medical aid without which this study would not have been possible.

Finally, the author expresses his deep gratitude to the ten subjects who had the courage to take part in this experiment with the knowledge that they would probably experience great physical discomfort.

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CHAPTER I

INTRODUCTION

It is apparent from a review of the literature concerning time estimation that there has been no investigation of the effect of vestibular vertigo upon the estimation of time. This may seem strange when consideration is made of the fact that there is an expanding body of research which deals separately with the areas of time estimation and vertigo. This study was designed to combine these two areas of research in order to investigate the effects of vestibular vertigo upon time estimation in humans.

The term 'vertigo' as used in this work will refer to vestibular vertigo. This type of vertigo is elicited by rotation of the head, with the following consequences: a sense of disequilibrium or dizziness; nystagmus; (and under conditions of extreme rotation), flushing due to increased peripheral circulation; increased heart and respiration rates; and nausea. Following is an example which demonstrates the dynamics underlying vestibular vertigo. When a person is rotated to the right with the head in an upright position, an inertial lag in the endolymph fluid of the right horizontal semicircular canal occurs. Thus the endolymph is made to move past hairlike sensory receptors (the crista) in the swelling of that semicircular canal (the ampulla). This in turn leads to not only consciousness of movement but also compensatory eye movements in a direction opposite to that of the rotation.

Since reflex eye movements occur during rotation as a result of the movement of the endolymph in the semicircular canals, these movements have been used in many studies as an indicator of vertigo. Harris (1963), used the duration and speed of this eye movement (nystagmus) as a test of the presence and severity of vertigo. A brief description of this phenomenon is called for due to the importance of nystagmus in the investigation of vertigo.

In the forementioned example of rotation to the right, stimulation of the crista occurred. The crista of the semicircular canals are connected by secondary nerve fibers to the extrinsic ocular muscles of the eyes. Impulses caused by the flow of endolymph during rotation initiate compensatory movements of the eyes. Nystagmus consists of two distinct phases. In the example in question, the first phase consists of a slow horizontal movement of the eyes to the left. The second phase consists of a rapid jerking back of the eyes to the right. During deceleration of rotation the nystagmic movements are reversed; that is, the slow phase is to the right and the fast phase is to the left.

Review of the Literature

It is important to note for studies requiring the production of vertigo some of the factors which affect the production and maintainance of vertigo. Habituation to rotation occurs if rotation is kept at a constant velocity due to the fact that no movement of the endolymph in the semicircular canals exists once the inertial lag occuring at the onset of rotation has been overcome, (Carlson, 1961; Langley, 1958). This fact suggested the use of energy pulses in rotation in the present work to maintain vertigo.

Further evidence for the inclusion of an energy pulse system of rotation is provided by the studies of Alexander, (1945a; 1945b), which attempted to specify the major causative factors in the production of motion sickness. These studies have relevence to the study of vestibular vertigo in that it is believed that motion sickness is at least partially due to the effect of endolymph movements in the vertical rather than the horizontal semicircular canals. Alexander studied the effects of variation of time intervals between accelerations and variation of the wave energies on the production and intensity of motion sickness.

It was found that the interval between equal energy pulses of acceleration (in an apparatus similar to an elevator), was a factor in the production of motion sickness. The optimal interval between accelerations was 1.1 se-conds. Periods above and below that interval did not have as much effect on the production of motion sickness. Alexander also found that when the interval between accelerations was held constant at 1.1 seconds the magnitude of the total wave energy was a greater factor in the production of motion sickness than was the interval between pulses.

These findings point out the necessity for providing pulses of energy during rotation rather than a constant rotation rate system. A pilot study was carried out to find the best manner in which this system could be usedand it was found that vertigo was produced and maint-ained at an optimal level when rotation was at a rate of approximately thirty-six R.P.M. for six revolutions of the chair and then allowed to decelerate for three revolutions;

the original rate of rotation (36 R.P.M.) being resumed.

The problem of habituation to rotation is most important in the current investigation since subjects make their estimates while experiencing vertigo during the rotation phase of the procedure. Research into this problem tends to support the observation that habituation does occur and that once it has occurred its effects are long lasting.

Forssman (1963), studied the response decline to repeated caloric irrigation of the inner ear and found that the physiological responses of vertigo habituated in a certain order. This order was found to be: diminution of dizziness sensations; followed by deareases in the total duration of nystagmus. Lindvall (1961) found comparable results in the ordering of habituation effects. Both researchers found that dysrhythmia of nystagmus and the eventaual disappearance of nystagmus were positive indicators of vertigo habituation. Thus it was decided that the experimenter would check subject nystagmus by visual examination both as an index of the presence of vertigo and the presence of habituation effects.

This precaution was considered most important to the current work since habituation effects have been proven to be of long standing duration. Studies indicate that evidence of habituation can be found on retest after: two weeks (Lindvall, 1961); three weeks (Guedry, 1965); and one month (Collins, 1964).

The literature yielded two factors which appear to aid in the control of habituation to rotation. These factors were blocking vision of the subjects during rotation and the role of activity-filled time during rotation.

Collins (1962), used both caloric and rotational methods of producing vertigo and found that continuous concentration on tasks maintained rotation symptoms well above the level of subjects who experienced vertigo without being required to engage in any activity. Collins (1964), found that when given a visual task to perform subjects habituated sooner than blindfolded controls. Guedry (1964), found supporting evidence which indicated that the use of vision facilitated the habituation to rotation.

In order to prevent or minimize the habituation effects it was therefore decided to blindfold subjects during the rotational phase and to reduce to a minimum the time when subjects were either not listening to instructions or responding to stimuli.

Investigation of the literature revealed one study which involved in part rotation and time estimation, although the rotation was in fact centrifugation. This study is worthy of note since it is hypothetically possible that some of the results of this study might have occurred due to symptoms similar to vestibular vertigo.

This study, conducted by Frankenhauser (1960), used a 'bucket centrifuge' to assess the subject's time sense, (by a variation of the method of reproduction) when the subjects were subjected to three gravities of radial acceleration. It was found that the subjects consistently overestimated the stimulus intervals; that is, they produced shorter estimates than the duration of the standard stimulus tones.

Vertigo which occurs during centrifugation is believed to be caused by anoxia of the brain centres and the inability of the body to rid brain tissues of carbon dioxide. It is worth speculation to ask whether the vertigo experienced in the centrifugation experiment was a prime factor in the distortion of time estimates in addition to the effects of brain anoxia.

Some discussion should now be make concerning time estimation itself. Methods of time estimation, their theoretical bias, their respective accuracy with regard to standard objective time, and so on are still subjects of much controversy.

Bindra and Waksberg (1956), attempted to bring some order to the study of time estimation by specifying terminology and methodology relevent to time estimation. They point out that much of the seemingly contradictory results of time estimation studies arises from not only the wide variation in methods used but also from the lack of a uniform terminology with which to describe results.

In the current study it was decided to employ both the method of reproduction and production in assessing time estimation. The method of production as defined by Bindra and Waksberg is operationally defined as follows: subject is given a verbal command instructing him to make a tone of a specified length; the subject then makes his estimate by pressing down a buzzer for the specified time. The method of reproduction is operationally defined as follows: the experimenter presents a tone of a certain duration; the subject is then required to reproduce that tone's duration by pressing down a buzzer until he perceives his tone to be equal to the experimenter's standard.

Characteristic differences in time estimates made under the methods of production and reproduction have not as yet been specified with any surety. There is some evidence which indicates that these two methods of time estimation are founded on different underlying basis, (Clausen, 1950; Ochberg, 1954). Evidence also exists which points to the fact that these two methods do not differ, (DuPreez, 1963). With reference to accuracy, Danziger (1963) points out that the estimates made under the 'estimation' methods (production and verbal estimation) are less accurate than reproduction methods. Danziger's findings are however the reverse of the findings of Siegman (1962), who found estimation methods more accurate than reproduction.

It is obvious then that the question of whether these methods of time estimation are really different and involve a different underlying basis is far from being answered. Differences between these two methods will be assessed in the current study both under conditions of rotation and non-rotation.

Connected with the question of the differences which may be present between these two methods of time estimation is the question of whether estimates made under these methods show evidence of characteristic trends.

Recent studies have attempted to discover if there was any type of trend exhibited in the estimates of subjects. These studies have mainly dealt with the method of reproduction and have shown that ther is a general linear trend revealed in the subjective time estimates (Mallick, 1962; Nelson, 1963; Richards, 1964).

The present study will therefore also attempt to determine the type of trend presented by estimates made under the method of production and the method of reproduction; under conditions of rotation and non-rotation.

Purpose of the Present Study

The present study was undertaken to investigate whether or not vertigo which was produced by the rotating-chair method had any effect upon time estimations made under the methods of reproduction and production. Thus investigation of whether rotation and vertigo were factors in the distortion of time estimates was studied.

The present study also was designed to investigate whether or not the estimates made under the method of production and the method of reproduction were different. That is, does the method of reproduction differ from the method of production with regard to their underlying basis.

Further, the present study was initiated to investigate the relationship of the estimate scores for the two methods and under the two conditions of rotation and non-rotation. Since some evidence exists which seems to indicate a linear trend in the estimates of reproduction scores, orthogonal tests for trend were undertaken to find out if linearity was a characteristic of the estimates of both methods and conditions.

CHAPTER II

METHODOLOGY AND PROCEDURE

Subjects

Ten adult male students who volunteered to take part in this experiement were chosen from the University of Windsor population.

The criteria for subject selection was as follows: (1), each S was a volunteer and was told that the procedure might make him ill and that he was free to refuse to take part in the study; (2), if the subject agreed to take part in the study he was required to give a relevent medical history and pass a medical examination, conducted by a licensed medical practioner, which ruled out any contra-indications to rotation and the induction of vertigo; (3), the subject was required to sign a 'release from responsibility form', releasing the experimenter, the Psychology Department, and the University of Windsor from responsibility for any adverse effects of rotation; (4), each subject was required to demonstrate ocular nystagmus and report feeling dizziness after experiencing rotation in the apparatus for a period of 30 seconds at a speed of 36 R.P.M. (A sample medical check list and Release from Responsibility form are presented in Appendix A.)

Apparatus

A standard office swivel chair was modified for use in the production of vertigo. Modification of the chair included: (1), the installation of bolts in the tilt-frame of the chair to stop the chair from tilting backwards; (2), a handle was affixed to the back of the chair to allow for manual rotation; (3), an adjustable head rest was installed on the chair's back which allowed subject's head to be held erect and in one plane; (4), a footrest was fixed to the front of the chair; (5), elongeated arm rests were placed on the chair to accomodate the battery powered tone producer and amplifier apparatus; (6), earphones were attached to the headrest assembly; (7), four copper bands were insulated and affixed to the spindle of the chair such that they articulated with four soft wire brushes fixed to the chair's base to allow electrical communication between the electrical apparatus on the chair and the recording and stimulus presentation devices apart from the chair.

The electrical section of the apparatus was connected as follows: the battery powered tone producer (a modified telegraph key), was connected to a buzzer which was situated over the antenna coil of a small transistor radio. Oscillation of the buzzer reed was picked up by the radio which was tuned to short wave frequency (and off commercial radio station of course). The volume control of the radio was thus used to modulate the volume of the buzzer and the volume of the buzzer was equalized with the volume of the stimulus buzzer which was recorded on tape. The battery powered amplifier was in circuit with the subject's earphones

The tone key was also wired such that when pressed it completed an internal circuit in the recording clock which was in another part of the laboratory. While the key was depressed the clock registered the elapsed time of the estimates. Circuitry to and from the chair was accomplished by the brush-copper band arrangement.

A standard tape recorder was used to present the instructions and stimulus tones to the subjects. Instructions and stimulus tones had been prerecorded and circuitry from the tape recorder to the subject's earphones was again accomplished by the brush-copper band mediators. The stimulus intervals prerecorded were: 2", 5", 7", and 10". They were recorded in random order and each interval was presented three times in random order.

A large clock with a sweep second hand was used to time rotational rates in order to get average rotation rates. A schematic representation of the apparatus is presented in Figure 1. below.

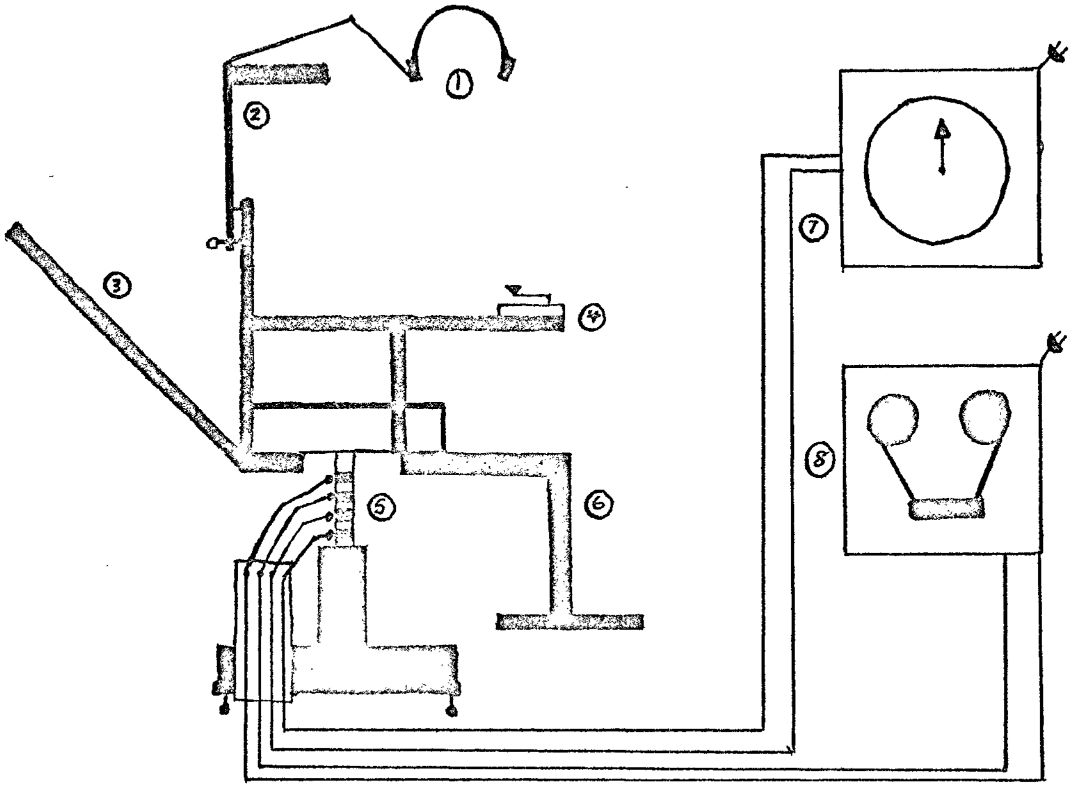

Figure 1. - Schematic representation of the apparatus. (1), Subject earphones; (2), adjustable headrest; (3), handle for rotation; (4), tone key and amplifier-circuit to recording clock, (5); brush-copper band circuit mediator; (6), footrest; (7), recording clock; (8), tape recorder - instructions and stimuli.

Procedure

Each subject was first seated in the chair and the headrest was adjusted to his height and was adjusted backward and forward such that the subject was comfortable and the horizontal semicircular canals were parallel to the floor. The positioning of the semicircular canals was accomplished by lining up an imaginary line drawn from the centre of the eye to the centre of the ear with the floor.

The earphones were then adjusted to the subject and the blindfold was put in place. All instructions for each of the four tasks which would be performed were given to the subjects while they were not rotating and while they were not experiencing any rotational symptoms.

Each subject was first given instructions which familiarized him with the operation of the tone producing key. These instructions were taped and were repeated twice as follows:

> Under your right hand is an apparatus for making a tone. When the key is pressed down you will hear a tone in your earphones. The length of that tone depends on how long you hold down that key. Press down the key a few times to acquaint yourself with how this tone maker works and how the tone that it makes sounds....... Dou you have any questions on how

the tone producer works? ...... Are you
able to hear the tone in your earphones clearly?

Once familiarization with the tone producer had occurred each subject was presented with the general instructions for the first estimation task. One-half of the subjects received the general instructions for the method of production first and the other five subjects received the instructions for the method of reproduction first. This was done to balance out any effects of possible learning cues which might have been present if one method aided in altering the estimates of the other unduly. General instructions for both of these groups were made for the condition and non-rotation first since it was felt that giving the rotation portion of the experiment first might cause too many adverse side effects which might have unduly influenced the results of the non-rotation estimates following. Thus, although the order of of presenting production and reproduction varied, the condition of non-rotation always preceded the condition of rotation in this study.

General instructions for the methods of production and reproduction, under conditions of rotation and non-rotation are presented in Appendix B. General instructions were repeated twice and subjects were given time to ask any questions regarding procedure.

The procedure for the group receiving the production task first will be used to show the procedural orders here. The procedure for the other group will of course be reversed. Subjects were first given the method instructions of the reproduction task , then were given the first stimulus tone via the earphones and tape recorder. They were free to make their response tone when they wished and once it was completed the next stimulus tone was presented as quickly as possible. The stimulus tones were 2", 5", 7", and 10", for all methods and conditions. The order of these intervals was however randomized to prevent order effects and three estimates were made on each duration under each task section.

The interval between stimulus conclusion and response initiation was not controlled by the experimenter in order that any anchoring effects of this interval would not be introduced.

After completion of the reproduction task the subjects proceeded to the production task. The general instructions were again given twice and the first verbal command was given. The specific verbal command was repeated twice in order to equilize the total time taken in instructions with that of the method of reproduction.

It was found that repetition of the instructions (of the general form: Now make a tone X number of seconds long), in a rather slow measured pace equalized the time taken in presenting the tone stimuli (2" + 5" + 7" + 10" x 3 = 72") of the reproduction method. Once again the response latency period was a dependent variable.

Following the completion of the non-rotation procedure subjects were given the instructions for the rotation condition. Again, instructions were given without rotation. Following the general instructions the subjects were rotated at speeds starting at 10 R.P.M. for 30" and proceeding by 6 R.P.M. increases (each for 30") up to a maximum of 36 R.P.M. for 30". This was done to determine the basal rate of rotation for each subject at which vertigo was experienced and at which a definite nystagmus was in evidence. It was found that response to rotation varied between subjects. That is, one subject experienced rather heavy signs of vertigo with heavy nystagmus at 16 R.P.M. Two others experienced the same level of vertigo at 28 R.P.-M. The remaining seven subjects required 36 R.P.M. to demonstrate these signs.

Once the basal rate of rotation had been found the subjects were rotated in the test situation. The same procedure was applicable to the rotation condition with regard to production and reproduction methods of estimation with the exception that all estimate instruction were given during actual rotation. It was found in the pilot study that breaking the two procedures into three sections each, to allow for the cessation of vertigo symptoms and thus attempt to decrease habituation effects, was not a practical procedure since subjects tended to become nauseated and unable to continue the estimations. This then necessitated running the twelve estimates in one block for each of the two methods. It was found that this procedure did not affect the subjective feeling of vertigo nor the appearance of nystagmic movements, but it did reduce sickness rates measurably. As it was, six of the ten subjects reported nausea and prolonged vertigo following the conclusion of the rotation procedure. One subject was omitted from the sample when he was unable to continue beyond the first method tested under the rotation condition. For three of the final ten subjects rotation rates had to be reduced to prevent outright illness; vertigo however did not disappear.

The procedure for stimulus presentation via the tape recorder, and the method of responding was the same as in the non-rotational procedure. The only difference in the rotation section of the experiment was that the specific estimate instructions weregiven while the subject was rotating and experiencing vertigo. Estimation procedure in each case five seconds following the subject's signal that he felt dizzy.

Following the completion of each of the production and reproduction the subjects were asked if they felt dizzy during the time that they were making their estimates. They were also checked for the ocular nystagmus by visual inspection by the experimenter. All subjects reported that they were dizzy most of the time during estimation and all showed some degree of ocular nystagmus even though this indicator varied greatly.

A word should be given to the method of rotation of subjects. The method of rotation was that subjects were rotated at their basal speed for six revolutions, allowed to coast without power pulses for three revolutions, and were then returned to their original basal speed immediately. During the time that their basal speed was being given, the experimenter added one pulse of energy per powered rotation revolution. This method proved to be of great value to the production and maintainance of vertigo since all subject claimed vertigo symptoms especially during the deceleration phases which had no power pulses.

The work of the pilot study had previously proved that constant rotation, even with the addition of power pulses did not provide the maintainance of vertigo symptoms. Using the method of acceleration with energy pulses and deceleration (giving a rebound vertigo effect) no loss of vertigo symptoms was recorded. This method of vertigo production was however probably most instrumental in causing symptoms of motion sickness.

CHAPTER III

PRESENTATION OF RESULTS

STATISTICAL ANALYSIS

Statistical analysis was performed on two types of scores: 'total deviation' scores and 'mean estimate' scores. Total deviation scores were found by summation (without regard for arithmetic signs) of the deviation of estimate durations from the durations of the stimulus intervals on which the estimates were made. Thus, for example, the three estimates made by Subject A on the stimulus interval 2" under the conditions of non-rotation, method of production, might have been 1.50", 2.50" and 4.00". The total deviation scores for these three estimates would have been .50" + .50" + 2.00" = 3.00".

This score is a measure of the total magnitude of the error made in estimation of single stimulus intervals. The rationale behind the use of this total error score is most applicable to situations requiring prediction of total error magnitude as opposed to average error magnitude. In cases where average error was needed and sufficient in prediction of error of estimation, the average error can be readily computed from the mean estimate scores (by subtraction of the mean estimate scores from the mean stimulus intervals), and the direction of the average deviation is then also readily available.

Mean estimate scores were found by taking the arithmetic average of the sum of the actual estimation scores. Therefore, in the example previously given, if the estimates for the interval 2" were 1.50", 2.50" and 4.00", the mean estimate score would be 1.50" + 2.50" + 4.00" = 8.00"/3 = 2.67".

Analysis of the mean estimate scores furnishes two important pieces of information. Mean estimate scores first of all indicate the average duration of time estimations. Secondly, they indicate the directional tendency of the estimate error; that is, they indicate whether the average estimates are larger or smaller than the stimulus intervals being estimated.

A three way factorial analysis of variance with repeated measures on all three factors was first conducted on the total deviation score data. The three main effects of the analysis were the three independent variables of the study: (A) rotation and non-rotation; (B), production and reproduction methods of estimation; (C), the four stimulus intervals being estimated, 2", 5", 7", and 10".

This analysis of variance showed that the total deviation made under the conditions of rotation and non-rotation did not differ under these conditions. The F observed on factor A was less than 1 , whereas the required F was 3.95 (.05 confidence level). Thus it would seem that the introduction of vertigo produced mechanically did not have any effect on the estimation of time when consideration of total deviation is analysed.

Significant statistical differences were however found on factors B and C. Factor B, the method of production and reproduction, yielded an F ratio of 19.92 where the required F was 6.95 (.01 confidence level), showing that total deviation under the production and reproduction methods differed. The F ratio for factor C proved to be 32.08 where the required F ($F_{.99}(3,95)$) was 3.97. This showed that the estimates made on the four standard intervals differed from each other. Thus estimates on different intervals produce different scores.

No interaction effects were found in this analysis. The analysis of variance summary table is presented in Table 1 following.

Table 1

Analysis of Variance Summary Table on Total Deviation Scores.

Source	S.S.	d.f.	M.S.	F. obs.
A - Rotation Non-rotation	3.844	1	3.844	<1
B - Production Reproduction	208.163	1	208.163	19.92
C - Simulus Intervals	1040.134	3	346.711	32.03
AB	.357	1	.357	<1
AC	1.712	3	.571	<1
BC	38.225	3	12.742	1.60
ABC	3.210	3	1.070	<1
Residual	1028.541	95	10.826	

$F_{.99}(1,95) = 6.95$ $F_{.99}(3,95) = 3.97$

$F_{.95}(1,95) = 3.95$ $F_{.95}(3,95) = 2.71$

Another three way factorial analysis of variance with the three factors being repeated measures was performed on the same factors as in the preceeding analysis of variance.

This analysis of mean estimates showed that there was no significant statistical difference in the mean scores of factor A , the rotation-non-rotation variable. Thus, once again, the varible rotation failed to show any statistical effect on the estimates made on the stimulus intervals.

No statistical difference was found on the independent variables production and reproduction methods of estimation, where the F observed was 1.33 (F req. = 3.95). Thus it was concluded that with respect to average estimate scores, there was no difference in the method of production and the method of reproduction.

Factor C (the standard stimulus intervals estimated) did however show statistical differences once more. The F ratio for the differences between these interval scores was 95.53 which was significant at the .01 level of confidence (where $F_{.99}(3,95) = 6.95$). It was concluded that the estimates made on the four intervals were different from each other.

This analysis of variance failed to demonstrate any statistically significant differences. Table 2 presents the summary of this analysis of variance. Computational formulae for these preceeding analysis are presented in

Appendix C.

Table 2

Analysis of Variance Summary Table on Mean Estimate Scores

Source	S.S.	d.f.	M.S.	F. obs.
A - Rotation Non-rotation	3.931	1	3.931	1.58
B - Production Reproduction	3.306	1	3.306	1.33
C - Stimulus Intervals	713.007	3	237.669	95.53
AB	.523	1	.523	<1
AC	1.001	3	.334	<1
BC	1.077	3	.359	<1
ABC	1.210	3	.403	<1
Residual	236.505	95	2.488	

$F_{.99}\ (1,95) = 6.95$ $\quad$ $F_{.99}\ (3,95) = 3.97$

$F_{.95}\ (1,95) = 3.95$ $\quad$ $F_{.95}\ (3,95) = 2.71$

Graphic Analysis

Graphic analysis was made on both the total deviation scores and mean estimate scores. The graphic analysis was attempted to investigate the relationships between rotation and non-rotation conditions, the two methods of estimation in terms of both error and average estimate measures.

Figure 2 presented below, is the graphic representation of the total deviation scores on the four stimulus intervals made under the methods of production and reproduction. Since there was no significant difference between total deviation scores of the rotation and non-rotation conditions, the scores represented in Figure 2 are for deviations under both conditions.

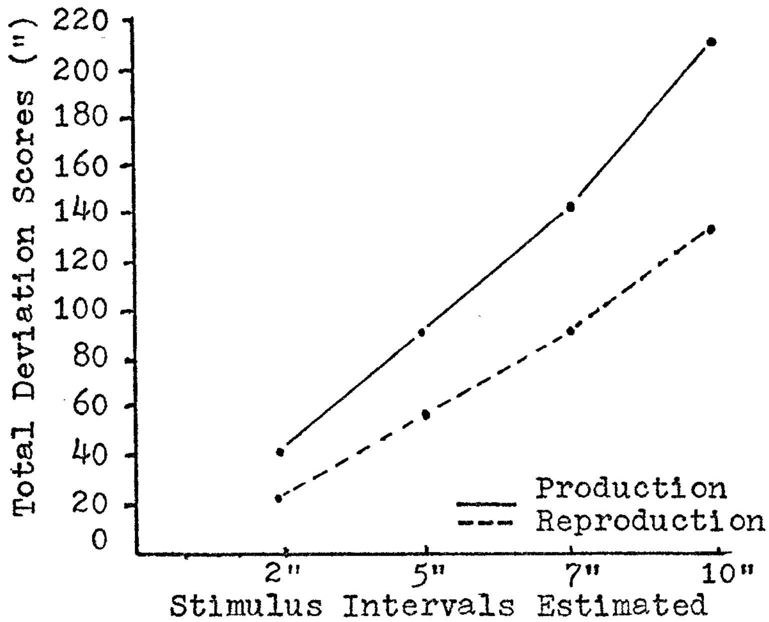

Figure 2. Graphic representation of total deviation scores of the methods of reproduction and production.

It is clear from the inspection of the graphic data of total deviation scores that the magnitude of total error increases proportionally with increases in the magnitude of the stimulus interval being estimated. That is true of both the total deviation scores of both methods.

It is also evident that the total error of the estimates for the method of production are greater than the total err for the same estimate intervals for the method of production. That is, at each level of time estimation tested , the error of the method of production is greater than that of the method of reproduction. The differences in total deviation scores were of course proven to be statistically different in the analysis of variance of total deviation scores previously presented.

Figure 3 is the graphic representation of the mean estimate scores made in the estimation of the four time intervals under the methods of production and reproduction. Once again the scores represented in Figure 3 are mean estimate scores for the two methods under both the conditions of rotation and non-rotation.

Inspection of Figure 3 reveals that there is no difference in the scores of the methods of production and reproduction. This fact was clear from the analysis of variance on mean estimate scores but it is still evident that with regard to mean estimates that the method of reproduction is slightly more accurate than the method of production even though the method of reproduction is not statistically proven to be more accurate.

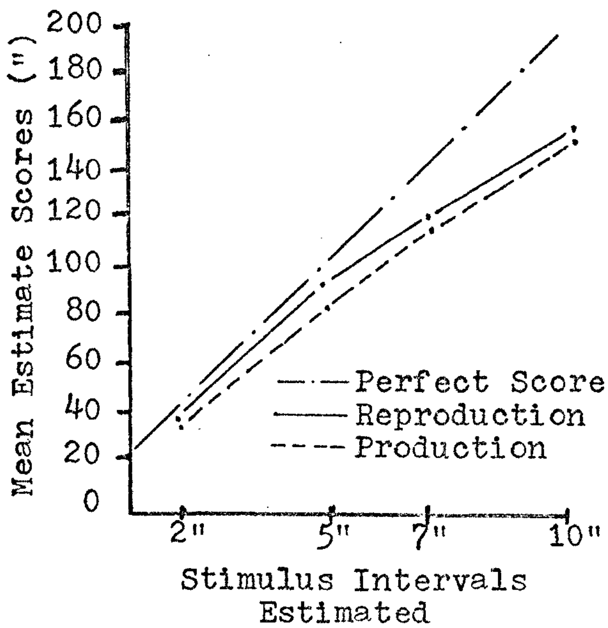

Figure 3. Graphic representation of mean estimate scores of the methods of reproduction and production.

Since it was found in the inspection of Fig. 2 that there was a difference in the total magnitude of the method of reproduction and the method of production, and that there was greater total error in the method of production with respect to the plots of Fig. 3 it could be assumed that the total error was probably negative in direction. To explain, since the average error scores represented in Fig. 3 are all negative with respect to objective time (represented by the perfect score), the average error is also negative in direction. That is, the average error is in the direction of underestimating the stimulus intervals.

Analysis of Trend

Since initial graphing of the estimates made under all conditions and methods appeared to be linear in form it was decided to investigate the linearity of these estimates. Orthogonal tests of trend were completed on the total deviation scores and the mean estimate scores for the totals of: the production-non-rotation condition; the reproduction-non-rotation condition; the reproduction rotation condition; the production rotation condition. the total estimates of the production method; and the total estimates of the reproduction method. All estimation scores were tested for linear, quadratic, and cubic trend.

The results of the orthogonal tests for trend are presented in Table 3 in summary form. The results show that with the exception of the mean estimate scores for the reproduction method-rotation condition which showed a significant cubic trend, all scores tested were found to follow a significant linear trend with no other trend exhibited.

Table 3

Summary Table for Orthogonal Tests of Trend

	Condition	F lin.	F quad.	F cub.	F crit
Mean Estimate Scores	Prod-No-Rot.	35.43	<1	<1	7.41
	Prod-Rot.	176.04	<1	1.08	7.41
	Reprod-No-Rot.	46.15	<1	<1	7.41
	Reprod-Rot.	204.42	2.18	20.53	7.41
	Prod-Total	29.28	<1	<1	7.02
	Reprod-Total	160.01	1.05	2.43	7.02
Total Deviation Scores	Prod-No-Rot.	19.40	<1	<1	7.41
	Prod-Rot.	54.62	1.20	<1	7.41
	Reprod-No-Rot.	30.65	1.77	<1	7.41
	Reprod-Rot.	28.66	<1	<1	7.41
	Prod-Total	60.47	<1	<1	7.02
	Reprod-Total	62.23	<1	<1	7.02

As a supplementary test, the scores were graphed on log.-log. paper to investigate the possibility that the linearity of the scores was due to a power function. All scores formed straight line plots on the log.-log. paper demonstrating the existance of a power function in the increasing function of the mean estimate scores and the total deviation scores.

CHAPTER IV

DISCUSSION OF RESULTS

From the statistical and graphic analysis of the data, both in terms of error scores and average estimates it is evident that rotation and vertigo did not have an effect on the estimation of the time intervals specified in this study as 2", 5", 7", and 10". This finding may be due to the fact that vertigo has no effect on time estimation whatever. But there is also the possiblility that the apparent lack of effect found was due to some uncontrolled factors in the experimental procedure. It seems wise to outline some of these possible weakpoints in the present procedure if for no other reason than to suggest changes to be made for further research.

One of the first criticisms of the present study was that symptoms of vertigo were not constantly present during the presentation of the stimulus intervals and during the response times of the rotational phase of the procedure. The energy pulse system of rotation, even with the addition of an acceleration-deceleration procedure was not sufficient to maintain symptoms of vertigo at all times during rotation. For example, during the pulse phase of the rotation, subjects reported that dizziness tended to wear off. During the deceleration phase, the subjects reported feeling extreme dizziness. Thus the subjects reportedly alternated extreme dizziness, with a diminution of dizziness and the reception of instructions and the production of estimates may have occurred in either or both of these phases.

Another criticism of this procedure might have been that there was little objective checking of the objective state of the subjects other than for the visual observation of nystagmic signs. The visual inspection of the subjects' eyes was at best only a check on vertigo which was present at the conclusion of rotation and could only have registered the existence of a rebound vertigo. There was then no objective way of insuring that vertigo was occuring; of checking its constancy; or of checkibg its intensity. Perhaps vertigo must be much more intense with regard to the endolymph circulation and that subjective report by subjects on whether they felt dizzy measured only one symptom of vertigo which was more easily aroused than other more relevent symptoms.

It is worthy of note when this last point is taken into account to consider the use of anti- motion sickness drugs in this type of experimentation. Since subjects became ill most probably due to the rotational procedure, which was necessary for the production and maintainance of vertigo, it would seem worthwhile to administer drugs which would minimize incidence of illness. In addition, the use of such drugs might make the use of higher rotation rates practical and significant rotational effects might appear. Care must be taken however to insure that such drugs depress illness only and that they did not depress vertigo itself.

Once ver-y relevent criticism of this procedure was the use of a single group of subjects rather than several groups on the various methods and conditions. Even though the experimenter is convinced of the wisdom of using repeated measures on very small samples, it is possible that practice effects could have cancelled out rotational effects in this study. Similarly, the application of both the reproduction and production procedures might have caused some diminution of the vertigo effects. However, the balancing of the design by presenting half the subjects with the production methods first and the other half of the subjects the reproduction method first did not appear to be necessary from analysis of group ordering differences carried out as a supplementary check.

It is very possible that the results of this study were due to anxiety effects. The finding that the estimates were all negative in direction rather than positive for the smaller intervals and negative for the longer intervals (a generally accepted phenomenon) suggests that an anxiety interference hypothesis is most reasona-ble. This is almost inevitable since subjects were required to take a medical examination and sign a 'release' form. Such necessary procedures probably evoked some anxiety in the subjects which could have had a general overall depressing effect on subject estimates under all condiditions. Future study might attempt to evaluate anxiety levels of subjects previous to, during and following the induction of vertigo.

Finally, the effects of vertigo on time estimation might have been too small to be picked up on the recording instru-ments available to the experimenter. Increased sophistication of instrumentation with motorization of a larger rotating chair, telemetry to pick up physiological correlates of vertigo, and more sophisticated recording apparatus capable of measuring finer intervals would be highly suggested.

More research is obviously needed on these variables. However, in the light of the above criticisms, it must still be concluded that the results clearly show no effect of vertigo on the estimation of time intervals as specified in this experiment.

With reference to the differences in the methods of production and reproduction the data seems to have more positive implications. The results show that the two methods do differ with respect to the total error of estimation. The total error of the method of production as measured by total deviation scores was greater at all times than that of the method of reproduction.

The method of reproduction did not however appear to be different from the method of production with reference to average duration of estimates, or with reference to average deviation of estimates. Considering accuracy, the method of reproduction would seem to be somewhat more accurate than the method of production, but it must be emphasized that the differences in average accuracy were not found to be statistically supported.

The results showed that estimates under all procedures and conditions increased with increases in the stimulus interval estimated. However, all estimates (average estimates) were found to fall short of the stimulus interval values in terms of objective time. Average error then was negative in direction with respect to comparison with the stimulus interval value. This finding is surprising since it is generally accepted that short intervals tend to be overestimated (estimates are larger than the standard) and longer intervals tend to be underestimated (estimates are smaller than the standard).

Analysis of trend data and graphic analysis showed that the increases which occurred in estimates on the increasing standard intervals increased in a linear form. That is, the estimates increased in a form which could be described as regular. Estimates appeared to increase as a direct proportion to the stimulus magnitude. Total error also demonstrated linearity of function.

Further tests which called for the graphin of the estimates on log.-log. graph paper demonstrated that the estimates varied as the result of a power function. The finding that all estimate plots on the log.-log. paper described a linear best fit line was taken as an indication that increases in psychological time were in proportion to increases to objective time and that the increase was mediated by a ratio constant common in both. Stated in oversimplified terms , these increases in estimate duration (psychological time) tended to increase in a fractional manner in direct proportion to a ratio value of the stimulus duration. Thus even though subjective time seems to be linear in form with regard to increasing estimates, it is not parallel to the values of objective time.

CHAPTER V

SUMMARY AND CONCLUSIONS

This study was undertaken to investigate the effects of vestibular vertigo produced by the rotating-chair method upon the estimation of time intervals by the methods of production and reproduction.

The results suggest that there is no effect of vestibular vertigo upon time estimation. Some suggestions were made to account for possible nullifying factors which might have cancelled out the effect of vertigo upon time estimation. Several suggestions were made which might aid in redesigning procedures in future studies on this topic. These suggestions included: the possible use of anti-motion sickness drugs in rotational studies; the use of larger samples and the avoidance of possible learning and practice effects; monitoring of anxiety effects; the development of more sophisticated rotational and telemetric equipment.

Some support was found for the assumption that the underlying basis of the method of reproductiion is different from that of the method of production. It was found that the total error of the method of production as measured by total deviation scores was greater and statistically different from the total error of the method of reproduction. Thus it was concluded that the method of reproduction was less variant in error than the production method.

With regard to accuracy and average deviation of error in the scores of the two methods it was found that although there was better accuracy with estimates made under the method of reproduction, the method of production was not statistically different from the other method in accuracy and average deviation. All estimates made under these two conditions when averaged, overestimated the stimulus intervals. That is, the estimates were smaller than the stimulus intervals. The stimulus intervals estimated were 2", 5", 7", and 10".

The results of graphic analysis tended to indicate that the increases in subjective time (the estimates) were linear in form when plotted. This linear relationship between increases was shown to be linear only by the use of orthogonal tests for trend. Further graphing of the estimate on log.-log. paper showed that the estimate increases seemed to follow a power function relationship between objective time and subjective psychological time estimates.

APPENDIX A

Sample Medical Check List - for use in the examination of subjects taking part in the experimental programme.

1. Relevent previous serious illnesses and operations.

2. History of tinnitus____, loss of hearing ____, spontaneous vertigo or dizziness____, chronic ear infections____, perforated ear drums ____, Manier's disease_____, Mastoid problems ____.

3. History of relevent alergies; nasal and sinus trouble.

4. History of nervous diseases____, epilepsy ___, periods of unconsciousness ____, chronic headaches ____, brain injury ____, weakness of the arms or legs ____, loss of sensation _____, mental illness ____.

5. History of double vision ___, excessive tearing _____, eye infections _____.

6. Recent weight gain or loss ______, current state of appetite.

7. Presently on medication? Are intoxicants used regularly?

8. Physical examination of (1) ENT
   (2) Heart and Blood Pressure
   (3) Nervous system.

Comments: (Use reverse side if necessary)

Physician's Signature

____

Sample Release From Responsibility for Adverse Effects of Rotation During Exerimentation.

I ____________________ hereby agree to take part in an experimental procedure which will involve my being rotated in a rotary chair device. I have been examined by a physician and have been informed of possible adverse effects which may occur due to the rotation which I will experience. I hereby agree to release (1) the experimenter, (2), the officials of the Department of Psychology of the University of Windsor, (3) and the administration and corporate body of the University of Windsor, from responsibility for any adverse effects which may occur during or following experimentation.

Witness ______________________ Signed ______________________

Witness ______________________ Date ______________________

APPENDIX B

Instructions for the Method of Production under the Condition of Rotation (Delete bracketed parts for non-rotation condition).

In this part of the experiment, your task is to make tones of a certain length of time. You do this by pressing down the key under your right hand which produces a tone in you earphones.

I will tell you (while you are turning and while you are feeling dizzy) what length of tone you are to make. For example, (when you feel dizzy) you will hear me say - now make a tone X number of seconds long. I will repeat that instruction and after you have heard it twice press your key down for X number of seconds.

After you finish making that tone I will tell you what length of tone you are to make next. You may begin to make you tone any time after you have heard the instructions twice.

Do not attempt to measure the length of your tone by counting or by any other means. Just concentrate on listening to the tone you are making , until you feel it is the correct number of seconds long.

Do you have any questions as to what your task is?

(I will start turning you now. When you feel dizzy press down your key three times as a signal that we can start the experiment. This is most important since you must be feeling dizzy during this part of the experiment).

Instructions for the Method of Reproduction under the Condition of Rotation (Delete bracketed parts for non-rotation condition).

In this part of the experiment I am going to feed into your earphones a tone similar to the one that your tone key makes when you press it down. Listen closely to the tone and try to concentrate only on the tone. The tone you will hear will last a certain length of time.

Your task is to listen to that tone and when it ends make a tone, by pressing down your tone key , that is equal in length to the tone you heard. You may begin making your tone any time after the tone I have made ends.

Do not attempt to measure the length of my tone or your tone by counting or by any other means. Just concentrate on listening to my tone and listening to your tone until you feel that your tone is the correct length of time long.

(During this part of the experiment you will be turned around in the chair. The tones you will hear me make and the tones you will make will occur while you are spinning around and while you are feeling dizzy).

(Repeat signalling procedure instructions).

APPENDIX C

Computational Formulae for the Three Way Factorial Experiment - All Three Factors Repeated Measures

(1) $\frac{G^2}{npqr}$

(2) ΣX^2

(3) $\frac{\Sigma(Ai)^2}{nqr}$

(4) $\frac{\Sigma(Bj)^2}{npr}$

(5) $\frac{\Sigma(Ck)^2}{npq}$

(6) $\frac{\Sigma(ABij)^2}{nr}$

(7) $\frac{\Sigma(ACik)^2}{nq}$

(8) $\frac{\Sigma(BCjk)^2}{np}$

(9) $\frac{\Sigma(ABCijk)^2}{n}$

(10) $\frac{\Sigma(Pm)^2}{pqr}$

SSA = (3) - (1)
SSB = (4) - (1)
SSC = (5) - (1)

SSAB = (6) + (1) - (3) - (4)
SSAC = (7) + (1) - (3) - (5)
SSBC = (8) + (1) - (4) - (5)

SSABC = (9) + (3) + (4) + (5) -(1) - (6) - (7) - (8)

SSBetween = (10) - (1)
SSWithin = (2) - (10)
SSTotal = (2) - (1)
SSResidual = SSWithin - SS of all main effects and all interactions

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